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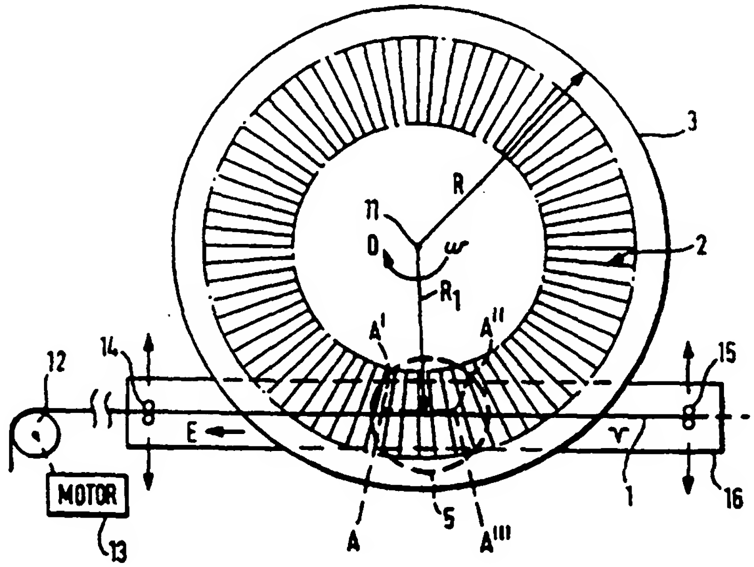
(54) Title: METHOD AND DEVICE FOR RECORDING A REFRACTIVE INDEX PATTERN IN AN OPTICAL MEDIUM



(57) **Abstract**

A device for recording a refractive index pattern in a photosensitive optical fibre consists of a rotary disc (3) formed with a phase mask in a circular pattern, which is rotated by an axis (11). The phase mask is illuminated with laser light in region (5) so that a moving interference pattern is formed. The optical fibre (1) is moved along a path in synchronism with the moving interference pattern so that the pattern becomes recorded in the fibre. The pattern can be formed continuously over long fibre lengths e.g. of the order of one metre.

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Method and Device for Recording a Refractive Index Pattern in an Optical Medium

Field of the invention

This invention relates to a device and method for recording a refractive index pattern in an optical medium and has particular application to forming a refractive index grating in an optical waveguide such as an optical fibre.

Background

It is known that the refractive index of an optical fibre can be altered by exposing it to high intensity light. Germanium doped fibre exhibits photosensitivity in this manner, particularly in response to ultraviolet (u.v.) radiation, and the effect can be used to form a so-called refractive index grating in the fibre. Reference is directed to K. O. Hill et al, "Photosensitivity in Optical Waveguides: Application to Reflection Filter Fabrication" Applied Physics Letters Vol. 32, No. 10 647 (1978). The grating can be formed by producing an optical interference pattern with two interfering beams, and exposing the optical fibre to the interference pattern, so as to record the pattern in the fibre. The interference pattern can be formed by directing an optical beam longitudinally through the fibre and reflecting it back along its path through the fibre, so as to produce a standing wave pattern, which becomes recorded in the fibre due to its photosensitivity. This method is difficult to control in practice and there is a limit on the length of fibre that can be exposed in this way.

In an alternative method, beams derived from a coherent source such as a laser are directed transversely of the length of the fibre, so as to interfere with one another and produce an interference pattern externally of the fibre, which becomes recorded in the fibre as a result of its photosensitivity. A block for producing an external interference pattern for this purpose is described in EP-A-0 523 084.

Another way of forming the grating is to use the phase mask in which the desired amplitude pattern has been recorded holographically as a mask pattern. The phase mask is placed adjacent to the fibre and illuminated with laser light so as to expose the fibre to the holographic pattern. Reference is directed to K. O. Hill et al "Bragg Grating Fabricated in Monomode Photosensitive Fibre by u.v. Exposure through a Phase Mask"Applied Physics Letters Vol. 62 No. 10, 1035 (1993), and also to R. Kashyap et al "Light-sensitive optical fibres and planar waveguides", BT Technol. J. Vol 11, No. 2 (1993).

For a general review of refractive index gratings, reference is directed to "Photosensitive Optical Fibres: Devices and Applications" R. Kashyap, Optical Fibre Technology 1, 17-34 (1994).

A problem with the prior techniques is that there is a limit to the length of refractive index grating that can be formed. With the technique described in EP-A-0 523 084, the length of fibre that can be exposed at any one time to the grating pattern, is limited by the width of the block that produces the external interference pattern and the coherence of the beam, and is typically of the order of 1 cm. When a phase mask is used, the holographic pattern is limited primarily by the length of the phase mask and the width of the beam of coherent light used to illuminate the mask. In practice, the width is limited to the order of 1 cm, although longer gratings have been attempted by a repetitive scanning technique as described by J. Martin et al "Novel Writing Technique of Long Highly Reflective in Fibre Gratings and Investigation of the linearly Chirped Component" Proc. Conference on Optical Fibre Communications, OFC '94 post deadline paper PD29-1, 138, 1994.

Refractive index gratings, which operate as Bragg gratings, have many applications in optical data communications systems, as discussed by Kashyap *supra*, and in particular, may be used as wavelength filters. The bandwidth of the filter is a function of the length of the grating along the fibre and it is

therefore desirable to be able to form gratings of extended length. Hitherto, this has proved difficult.

Summary of the invention

The present invention provides an alternative way of recording a refractive index pattern in an optical medium, which permits much longer gratings to be formed.

In accordance with the invention from a first aspect there is provided a device for recording a refractive index pattern in an optical medium that has a photosensitive refractive index, comprising means for producing a moving optical intensity pattern, and means for feeding an optical medium along a path past the pattern producing means during production of the moving pattern so as to record the pattern in the medium.

The pattern producing means may include means disposed in a loop for forming the pattern, and the feeding means may be operative to feed the optical medium along the path during circulation of the loop so as to record the pattern longitudinally in the optical medium.

The invention has particular application to recording refractive index gratings in optical waveguides such as optical fibres.

The pattern producing means may include a phase mask arranged in a closed loop so that upon rotation of the loop, the pattern is recorded repetitively. For optical fibres, the pattern may be recorded longitudinally along the length of the fibre so as to form a grating of extended length, for example of the order of one metre or longer.

The phase mask may be formed on a rotary disc. Alternatively, the phase mask may be recorded on the surface of a cylindrical member, so arranged that radiation can be directed from within so as to form the optical pattern

exteriorly.

The rotary member may be made of silica and the phase mask may comprise spatially periodic undulations formed in a surface of the member.

The invention also includes a method of recording a refractive index pattern in an optical medium that includes an elongate path for optical radiation with a photosensitive refractive index, the method comprising using a device to produce an optical intensity pattern such that it is recorded a plurality of times along the length of the path in the optical medium.

The invention further includes a method of recording a refractive index pattern in an optical medium that includes an elongate path for optical radiation with a photosensitive refractive index, the method comprising sequentially recording substantially contiguous optical intensity component patterns along the length of the path in the optical medium such as to form an elongate resultant pattern from said components.

In another aspect, the invention provides a device for recording a refractive index pattern in an optical medium that has a photosensitive refractive index, comprising means arranged in a loop for producing an optical intensity pattern, and means for exposing the medium to the pattern so as to record it linearly in the medium.

Thus, in accordance with the invention, patterns of extended length may be recorded in the medium.

Brief description of the drawings

In order that the invention may be more fully understood, embodiments thereof will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a schematic plan view of a first device for recording a refractive

index pattern in an optical fibre;

Figure 2 is an enlarged sectional view taken along the line A-A'-A"-A"' shown in Figure 1;

Figure 3 is a schematic diagram of the disc shown in Figure 1, for explaining the radial disposition of the phase mask recorded on the disc;

Figure 4 is a schematic illustration of a second embodiment according to the invention;

Figure 5 is a schematic illustration of a third embodiment according to the invention;

Figure 6 is a schematic illustration of a fourth embodiment according to the invention;

Figure 7 is a schematic illustration of a fifth embodiment according to the invention;

Figure 8 is an illustration of a fibre including a refractive index grating formed in accordance with the fifth embodiment;

Figure 9 is an schematic plan view of another device for recording a refractive index grating in an optical fibre, in accordance with the invention; and

Figure 10 is a sectional view of the device shown in Figure 9.

Detailed description

Referring firstly to Figure 1, an optical refractive index grating is recorded in a photosensitive optical fibre 1 by means of an optical interference pattern that is produced by the use of a phase mask 2 recorded in a rotary disc 3. Figure 2 shows a section through the disc along the line A-A'-A"-A"' of Figure 1. In Figure 2, the phase mask can be seen more clearly, and consists of a series of radially extending grooves 4 cut in the surface of the disc so as to act as a diffraction grating. The disc is illuminated with coherent light from a laser at a fixed location, operating at a u.v. wavelength e.g. 244 nm, as illustrated by arrows B. The lateral extent of illumination is illustrated schematically in Figure 1 by circle 5 shown in dotted outline. The disc 3 is made of material that is transparent to the u.v. light from the laser and conveniently is formed of fused silica with a refractive index n = 1.46. In a

typical example, the disc has a radius R of 40 mm and a thickness $x = 3$ mm. The groves 4 may be formed by techniques which are conventional *per se*, such as E-beam lithography and selective etching, or by photolithography using a mask followed by selective etching. For further details of these conventional techniques, reference is directed to C. Dix and P. F. McKee, J. Vac. Science Technology Vol 10, No. 6 pp 266-267 (1992). A typical depth of the grooves 4 is 0.26 μm with the spatial periodicity Λ of the pattern shown in Figure 2 being of the order of 1 μm.

The laser light incident on the disc 3 in direction B is diffracted by the phase mask pattern 2 so as to form first and second diffracted beams 6, 7, which overlap and form a diffraction pattern in region C. The optical fibre 1 extends through the region of the diffraction pattern. The optical fibre consists of a core 8 surrounded by a cladding 9 which has a lower refractive index than the core. The fibre is typically a silica fibre and has a photosensitive core which may be co-doped with Ge and B. The core is photosensitive to the u.v. light from the laser at wavelength 244 nm. As a result, the refractive index pattern becomes recorded in the core 8 of the fibre 1 in a manner well known *per se*, so as to form a refractive pattern shown in dotted outline in Figure 2, consisting of a series of regions of relatively high and low refractive index 10a, 10b along the length of the exposed region of the fibre. Reference is directed to G. Meltz et al "Formation of Bragg Gratings and Optical Fibres by Transverse Holographic Method" Opt. Lett. Vol. 14, No. 15 823 (1989) for a general discussion of recording the refractive index pattern in the grating. The diameter of the core 8 of the fibre may be of the order of 8μm and the exterior diameter of the cladding 9 may be of the order of 125μm. The length of the fibre C that is exposed to the interference pattern, may be of the order of 1 mm.

The present invention permits the refractive index grating to be written in much longer lengths of the fibre than the region C. Referring to Figure 1, the disc 3 is mounted for rotation about a central axis 11 in the direction of

arrow D, and is driven by a motor (not shown). The phase mask 2 is arranged in a circular, continuous loop, which is concentric with the axis 11 of rotation of the disc 3. Thus, as the disc is rotated, it passes through the fixed region of illumination 5 produced by the laser and as a result, a moving interference pattern is formed within the region 5, the pattern rotating at the same rate as the disc 3.

The optical fibre 1 is driven through the region 5 so as to be in synchronism with the rotating interference pattern. To this end, the optical fibre is pulled by a pulley 12 driven by a motor 13 through guide rollers 14, 15, mounted on a common support 16. The fibre 1 subtends a radius R_1 with respect to the axis 11 of the disc 3. In order to achieve synchronism of the rotating interference pattern and the moving fibre 1, the following condition needs to be satisfied:

$$\omega R_1 = v$$

where v is the speed on movement of the fibre 1 in direction E and ω is the rate of rotation of the disc 3.

The speed v of the fibre and the rate of rotation ω of the disc are selected to provide an adequate exposure time of the fibre to the interference pattern 5 in order to achieve satisfactory recording of the pattern in the fibre core 8. In one example, the fibre speed v was selected to produce a fibre exposure time of the order of several minutes per mm.

The spatial periodicity of the pattern recorded in the fibre can be adjusted by moving the support 16 shown in Figure 1 radially inwardly or outwardly of the disc. This will now be explained in more detail with reference to Figure 3 which shows two radial grooves 4 of the phase mask 2 on an expanded scale, spaced apart by a small angle $\delta\theta$. For a particular radius R_0 the spatial periodicity of the pattern Λ_0 is given by:

$$R_0\,\delta\theta = \Lambda_0$$

Similarly, for a slightly larger radius R', the spatial periodicity Λ' is given by:

$$R' \ \delta\theta = \Lambda'$$

Thus, it can be shown that $\Lambda' = (R'/R_0)\,\Lambda_0$

Accordingly, the spatial periodicity Λ' of the pattern can be selected by moving radially inwardly or outwardly of the disc 3. In the embodiment of Figure 1, this is achieved by means of the movable support 16 which permits the fibre 1 to be shifted inwardly or outwardly so as to select the desired spatial periodicity of the phase mask and hence the pattern recorded in the fibre. This can be used for fine tuning the pattern recorded in the fibre or, by moving over larger distances to select the periodicity itself. Referring to Figure 3, three bands of the radial phase mask pattern 2 are shown, referenced 2a, b and c, for recording refractive index gratings in the region of 1.5 μm, 1.3 μm and 0.85 μm respectively. The corresponding value of Λ for the mask pattern was 1.066 μm, 0.904 μm and 0.579 μm respectively.

Figure 4 illustrates an alternative embodiment in which the phase mask 2 is recorded on the exterior surface of a hollow cylindrical body 17 which is rotated in the direction of arrow D by motor 18. The body 17 is transparent to the u.v. illuminating light from the laser (not shown), which is directed on path B onto a mirror 19 within the body 17, so as to be reflected through the body to the exterior thereof, so that the phase mask pattern is formed radially outwardly of the cylindrical body 17.

The fibre 1 is driven along a path in contact with the exterior surface of the body 17 so that the interference pattern is recorded in the fibre. As in Figure 1, the fibre is pulled by pulley 12 driven by motor 13. The speed of motor 13 may be controlled over electrical line 20 by control means 21 associated with the motor 18 in order to maintain synchronism of th rotating interference pattern produced by the phase mask, and the drive speed for the fibre 1. The arrangement of Figure 4 has the advantage that the fibre may be exposed for a

longer period of time than in the arrangement of Figure 1 due to the fact that it is maintained at a constant radius relative to the axis of rotation of the body 17.

Many variations and modifications to the above described devices are possible. For example, in the embodiment of Figure 4, the cylindrical body can be solid, and the laser beam can be directed obliquely through its upper surface, to avoid use of the mirror 19. Also, the cylindrical body may be conical so that by moving the fibre drive arrangements upwardly and downwardly, the spatial periodicity of the pattern can be altered and wavelength tuned. Also, for the embodiment of Figure 4, by tensioning the fibre, fine tuning of the recorded pattern periodicity can be achieved. The fibre can be wrapped more than once around the cylindrical body.

Also, for both of the described embodiments, changes in the recorded pattern can be achieved along the length of the recorded pattern, for example by introducing small changes in the relative speed of the fibre v and the rate of rotation ω of the phase mask pattern 2. This process can be used to introduce a chirp in the recorded pattern. Also, the phase mask pattern may be configured to produce a blazed grating in the fibre.

Another embodiment will now be described with reference to Figure 5, which can be considered as a modification of Figure 4. In this arrangement, the cylindrical body 17, with the phase mask pattern 2, is stationary, and the fibre 1 is wrapped in a plurality of turns 20 around the circular phase mask. The mirror 19 is mounted on a rotary shaft 20 driven by a motor (not shown) so that light beam B from laser 21, is scanned in a circular path around the pattern. Thus, if the pattern around the drum is considered as a component pattern, the component pattern is recorded a plurality of times in respective turns of the fibre around the drum, in a contiguous relationship. In this way the refractive index grating is recorded as a continuous pattern a plurality of times in the turns 20 of the fibre 1 wrapped around the cylindrical body 17.

Referring now to Figure 6, a fourth embodiment of the invention is shown, in which a chirped refractive index grating is recorded in a spiral planar waveguide 22 which is formed in the surface of a silica plate 23, in a manner well known *per se*. For example, the silica plate 23 may be provided with a photosensitive surface coating by Ge:B co-doping techniques, which is then photo etched to form the spiral pattern. It will be seen that the waveguide 22 is arranged generally concentric with point X.

The plate 23 is overlaid by a phase mask 2 recorded in a glass plate 24. The phase mask is formed in the same way as the mask 2 shown in Figures 1 and 2. However, the plate 24 does not rotate. The centre 11 of the pattern 2 is arranged coaxially with the centre X of the spiral waveguide pattern on plate 23. The laser 21 is mounted on means (not shown) so as to move in a circular path 25 concentric with the circular pattern 2 of the phase mask. The beam B from the laser illuminates the phase mask and accordingly records the refractive index pattern from it in the spiral waveguide 22. Alternatively, the u.v. beam B may be fixed and the assembly of the waveguide 22 and the phase mask may be correspondingly moved to achieve the scanning.

In view of the radially outwardly extending ridges in the pattern 2, the periodic spacing of the pattern recorded in the spiral waveguide 22 is smaller in the radially innermost turns of the spiral pattern and increases progressively in the outer turns. Consequently, the pattern is imparted with a chirp. Thus, the fourth embodiment permits the recording of a chirped filter that can be used for optical telecommunications purposes, for example to recover the effects of dispersion along a long length of optical fibre.

Modifications of the embodiment of Figure 6 include the use of an optical fibre arranged in a spiral pattern or in a coil, instead of the planar waveguide shown.

A fifth embodiment of the invention is shown in Figure 7, in which a planar

phase mask 26 is used, aligned with a length of an optical fibre 1. In order to record the grating in the waveguide, the beam B of the laser 21 is scanned longitudinally of the length of the phase mask 26, in the direction of arrows E-E'. The fibre is held at each end of the phase mask by means of clamps 27, 28 that include piezo electric elements that may be driven by an electrical oscillating source 29, which causes the fibre to be stretched and relaxed longitudinally in an oscillatory manner, which is relatively rapid compared to the rate of scanning of the beam B. The cyclic stretching and relaxing of the fibre 1 results in apodisation of the recorded pattern and further details, reference is directed to our PCT/GB96/03079 filed on 12 December 1996.

The apparatus shown in Figure 7 can be used to record a series of component refractive index grating patterns which are substantially contiguous, along the length of the fibre 1. Thus, when the first grating pattern has been recorded as just described, the clamps 27, 28 are released and the fibre is slid longitudinally between the clamps by an amount corresponding to the length of the phase mask 26. The clamps are then tightened again and the recording process is repeated so as to form a second grating pattern substantially contiguous with the first pattern. The process may be repeated many times in order to form a resultant pattern of sufficient length. The apodisation performed by means of the clamps 27, 28 and the oscillator 29 need not be performed on the recorded pattern components between the end components of the resultant, long grating. Apodisation need only be applied at the ends of the resultant recorded pattern. This can be achieved by stretching the fibre in an oscillatory manner with only one of the piezo devices, i.e. from one end only, for each end pattern. The contiguous junctions between adjacent pattern components recorded in the fibre may be trimmed using u.v. light in order to achieve a phase coherence of the pattern components, the u.v. trimming being carried out as described in our PCT/GB94/00180 filed on 31 January 1994.

Thus, it will be understood that the process can be repeated on the same fibre

at different, substantially contiguous locations with the same phase mask to produce a long grating, in which case apodisation by stretching will be applied asymmetrically at the ends of the long pattern. Alternatively, phase masks with different spatial periodicities can be used to produce a chirped pattern. The recorded patterns can be matched at their junctions by the apodisation process or, no apodisation may be applied to match the junctions.

A resultant, recorded pattern is shown in an optical fibre in Figure 8. The pattern consists of a series of component patterns 10^1, 10^2, 10^3 recorded in a contiguous manner along the length of the fibre 1. No apodisation is applied by stretching at the joins between the patterns 10 in this example. The optical fibre may be of the same dimensions and photosensitive characteristics as described in relation to Figure 1. Surprisingly, the contiguous, recorded patterns do not necessarily require apodisation at their junctions in order to achieve satisfactory matching.

Another example of the invention is shown in Figures 9 and 10, which can be considered as a modification of the embodiment shown in Figures 1 and 2. Referring to Figures 9 and 10, the rotary disc 3 is provided with a phase mask 2 in the manner previously described. A capstan 30 is attached to the disc 3 and the arrangement is mounted for rotation about a shaft 31. A circular groove 32 is formed around the base of the capstan 30, which receives the optical fibre 1. As shown in Figure 9, the optical fibre is wrapped around the capstan 30 in the groove 32, and leads out of the groove to pulley 12 driven by motor 13. The shaft 31 is not driven. On operation of the motor 13, the pulley 12 drives the fibre 1 which causes the capstan 30 to be rotated together with the disc 3. Thus, the fibre is moved in a circular path by rotation of the capstan 30 in synchronism with the phase mask 2, so that exposure of the fibre can be carried out as described previously with reference to Figure 1. The advantage of the arrangement as compared with Figure 1 is that the fibre 1 and the phase mask 2 are held in strict synchronism during the exposure process.

The described devices have the advantage that fibres can be written with a grating having a length of one metre or more, which results in a refractive index grating with an ultra-narrow bandwidth or with a particular chirp.

Also, the phase mask pattern can be prepared in a number of different ways. For example, the pattern could be formed holographically in a thick photographic film, which could be in the form of a long belt which is run in synchronism through a pattern recording point where it is illuminated with laser radiation. The pattern need not necessarily be a holographic pattern but could be produced by a shadow mask. Many other modifications and variations will be apparent to those skilled in the art, falling within the scope of the claims hereinafter.

Claims

1. A device for recording a refractive index pattern in an optical medium (1) that has a photosensitive refractive index, comprising means (2, 3, 17) for producing a moving optical intensity pattern, and means (12, 13) for feeding the optical medium along a path past the pattern producing means during production of the moving pattern so as to record the pattern in the medium.

2. A device according to claim 1 wherein the optical pattern producing means includes means (2) disposed in a loop for forming the pattern, and the feeding means (12, 13) is operative to feed the optical medium along said path during circulation of the loop whereby to record the pattern longitudinally in the optical medium.

3. A device according to claim 1 or 2 including drive means (18) for driving the pattern producing means for producing said movement of the pattern.

4. A device according to claim 3 including control means (20) for controlling the relative rate of the pattern movement produced by the drive means and the rate of feed produced by the feeding means whereby to control characteristics of the pattern recorded in the optical medium.

5. A device according to claim 2, 3 or 4 wherein the loop (2) is a closed loop and the pattern is recorded repetitively.

6. A device according to claim 5 wherein the loop (2) is circular and disposed for rotation about a predetermined axis (11) to produce said circulation.

7. A device according to claim 6 wherein the pattern producing means comprises a rotary member (3, 17) with a phase mask (2) for forming the pattern.

8. A device according to claim 7 including a source of optical radiation (B) for illuminating the phase mask.

9. A device according to claim 7 or 8 wherein the rotary member comprises a disc mounted for rotation about its axis with the phase mask disposed in a circular loop around the axis.

10. A device according to claim 9 wherein the phase mask includes a series of mask elements (4) extending radially outwardly of the disc axis, disposed around the loop.

11. A device according to claim 10 wherein the feeding means (12, 13, 14, 15) is configured to feed a photosensitive optical fibre (1) past the disc.

12. A device according to claim 11 including means (16) for adjusting the radial distance between the fed fibre and the axis of the disc whereby to adjust the spatial periodicity of the recorded pattern.

13. A device according to claim 7 wherein the rotary member comprises a body (17) with a cylindrical surface mounted for rotation about its axis, with the phase mask (2) disposed in a loop around the body.

14. A device according to claim 13 wherein the body (17) is hollow and the optical radiation source is configured so that radiation therefrom is directed through the body from within so as to form said optical pattern exteriorly thereof.

15. A device according to any one of claims 7 to 14 wherein the rotary

member (3, 17) comprises a body of silica and the phase mask comprises spatially periodic undulations formed in the surface thereof.

16. A device according to claim 15 wherein the surface undulations (4) are formed by lithography and selective etching.

17. A method of recording a refractive index pattern in an optical medium (1) that includes an elongate path for optical radiation with a photosensitive refractive index, the method comprising using a device (2, 26) to produce an optical intensity pattern (C) such that it is recorded a plurality of times along the length of the path in the optical medium.

18. A method of recording a refractive index pattern in an optical medium (1) that includes an elongate path for optical radiation, with a photosensitive refractive index, the method comprising sequentially recording substantially contiguous optical intensity component patterns (10^1, 10^2, 10^3) along the length of the path in the optical medium such as to form an elongate resultant pattern from said components.

19. A method according to claim 18 including recording the component patterns using a phase mask (2, 26).

20. A method according to claim 19 including recording the component patterns using the same phase mask (2, 26).

21. A method according to claim 19 including recording the contiguous component patterns using different phase masks (26) for each said pattern (10^1, 10^2, 10^3).

22. A method according to claim 20 or 21 wherein the recorded patterns are chirped.

23. A method according to any one of claims 18 to 23 including apodising the resultant pattern at opposite ends.

24. A method according to any one of claims 18 to 24 including apodising the resultant pattern at opposite ends by asymmetrically stretching the optical medium during recording of the component patterns (10^1, 10^5) which form opposite ends of the resultant pattern.

25. An optical waveguide with a composite refractive index grating formed therein by a method according to any one of claims 18 to 24.

26. An optical waveguide with the contiguous component patterns not ben apodised at their junctions.

27. A device for recording a refractive index pattern in an optical medium (1) that has a photosensitive refractive index, comprising means (2) arranged in a loop for producing an optical intensity pattern, and means for exposing the medium to the pattern so as to record it linearly in the medium.

28. A device according to claim 26 wherein the loop is a closed loop, and said exposing means comprises means (19, 20) for scanning a beam of radiation (B) around the loop.

29. A device according to claim 27 including an optical fibre (1) in which said pattern is to be recorded, wound a plurality of times around the loop.

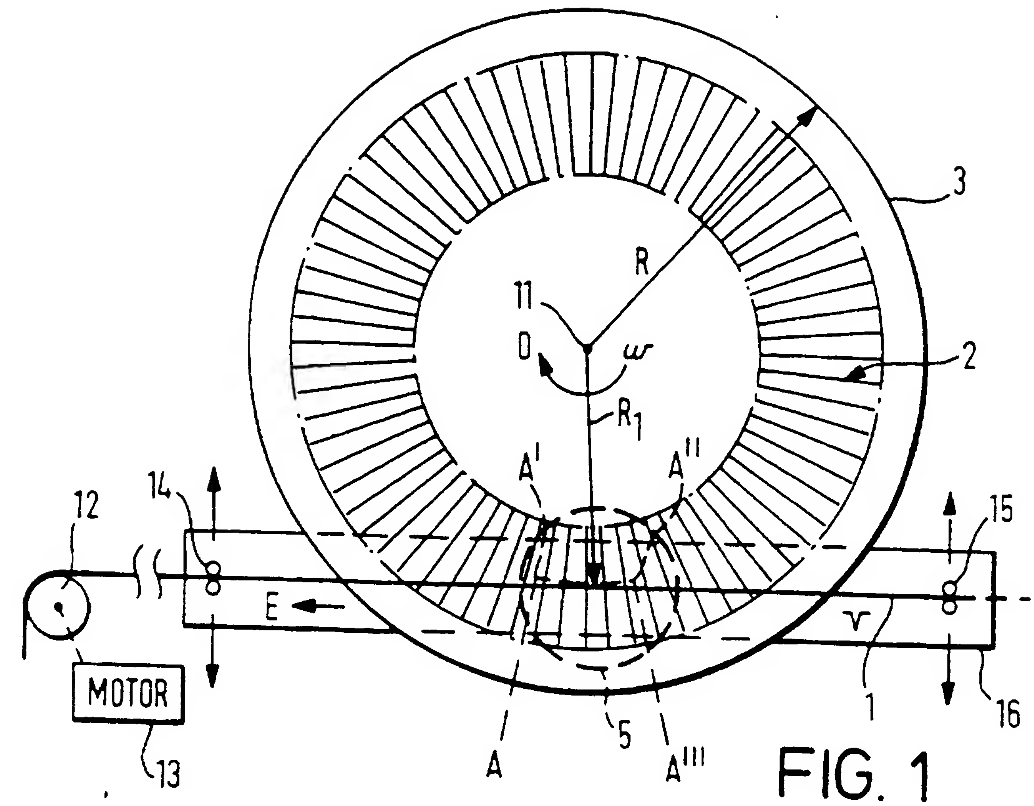
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FIG. 1

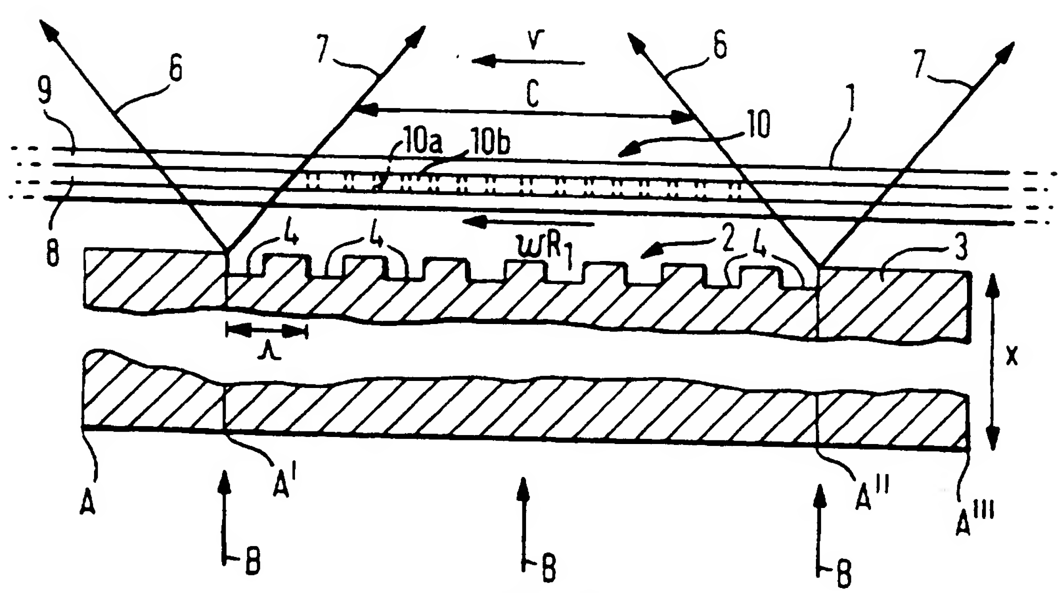
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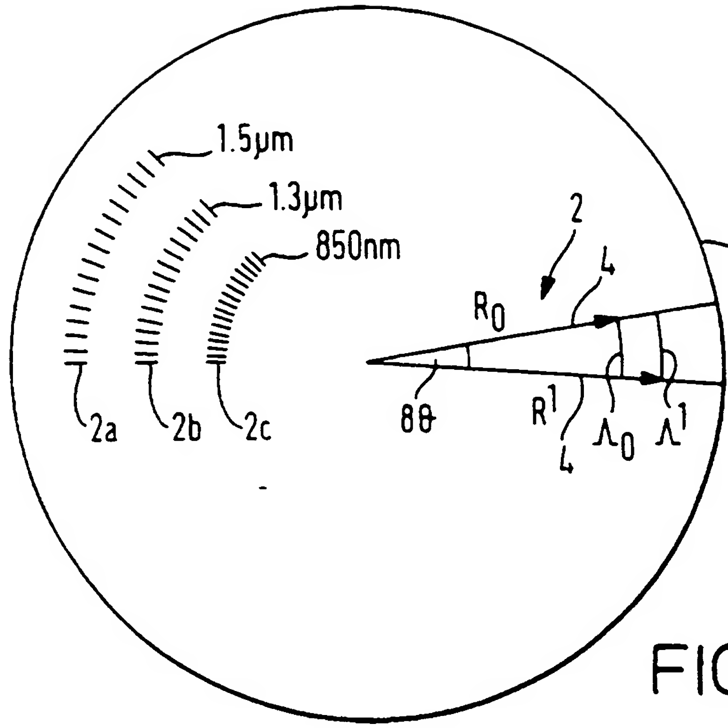
FIG. 2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1.3μm
850nm
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3
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4
2a
2b
2c

FIG. 3

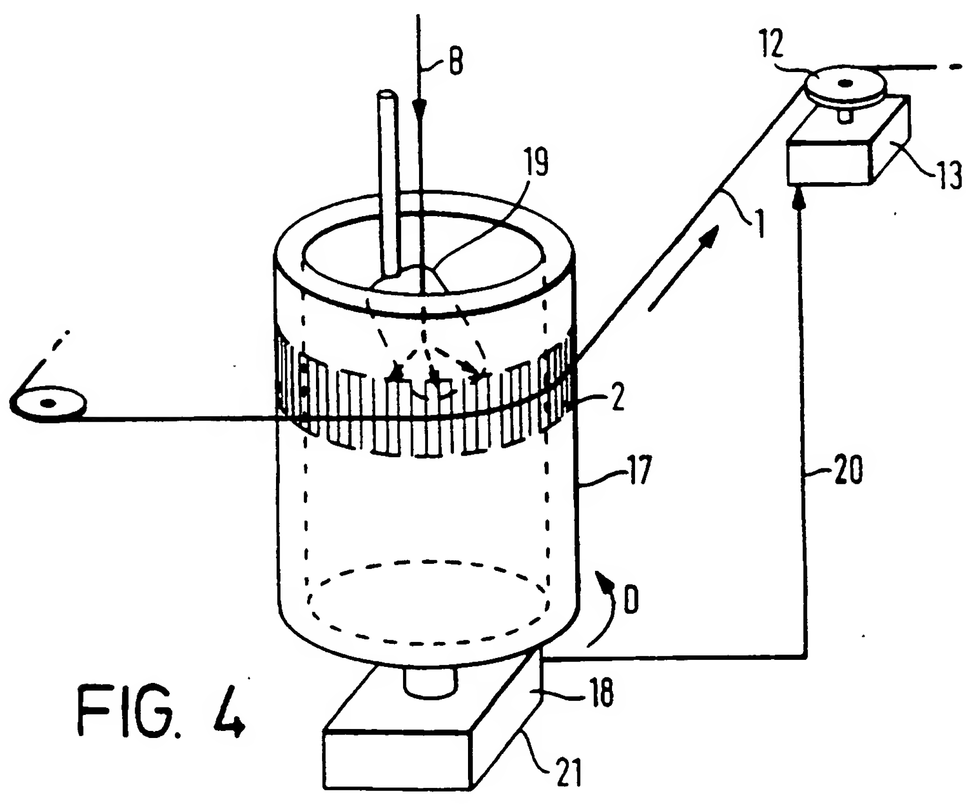
8
12
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FIG. 4

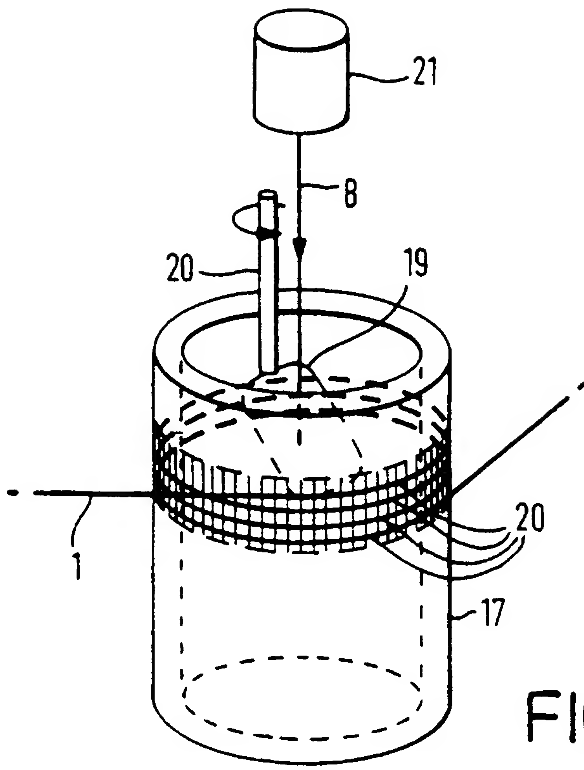

FIG. 5

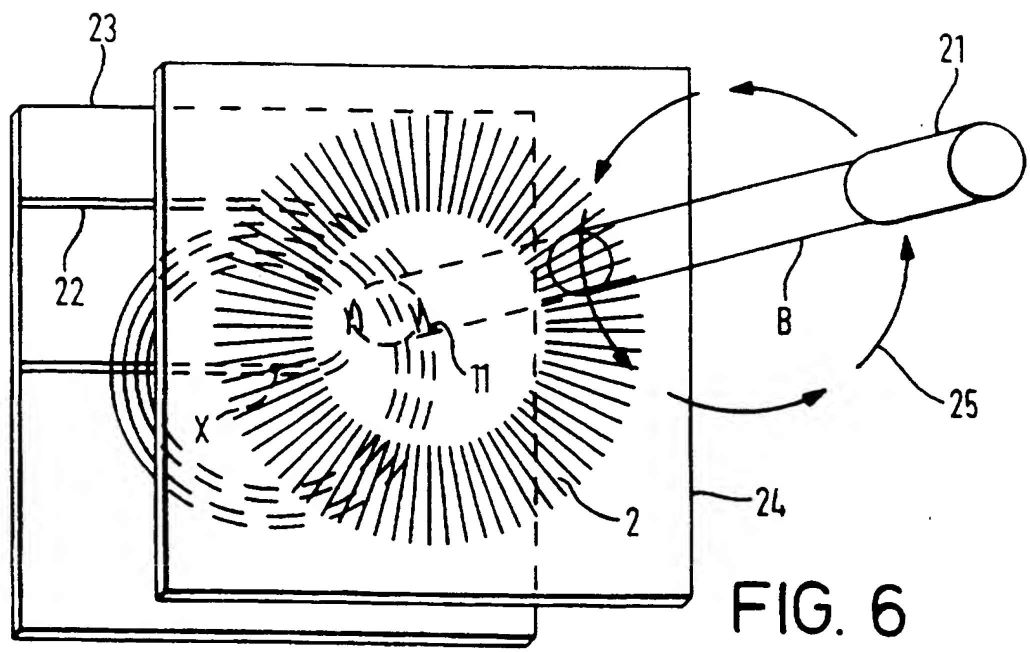

FIG. 6

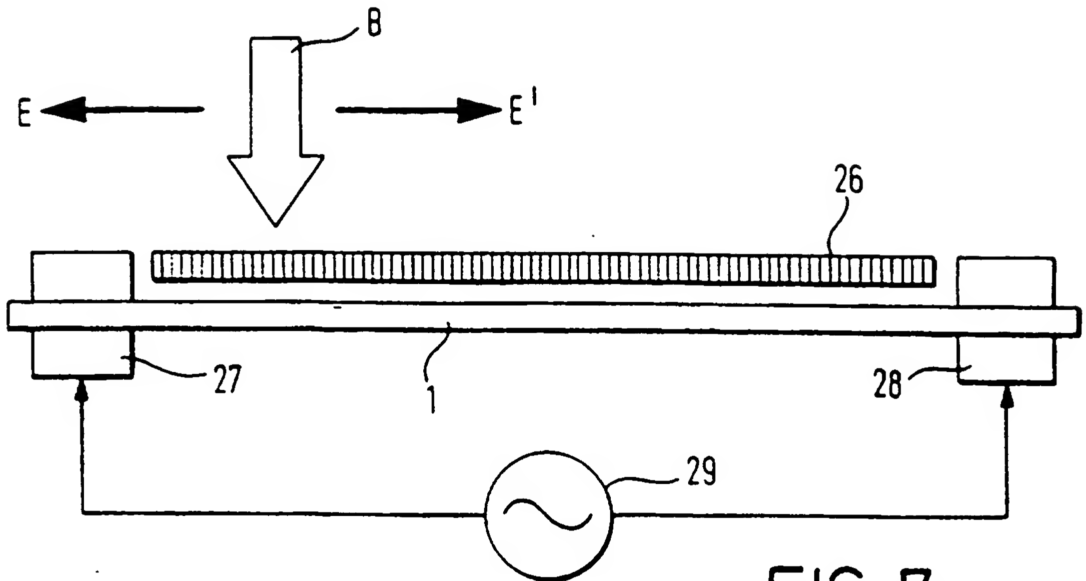

FIG. 7

FIG. 8

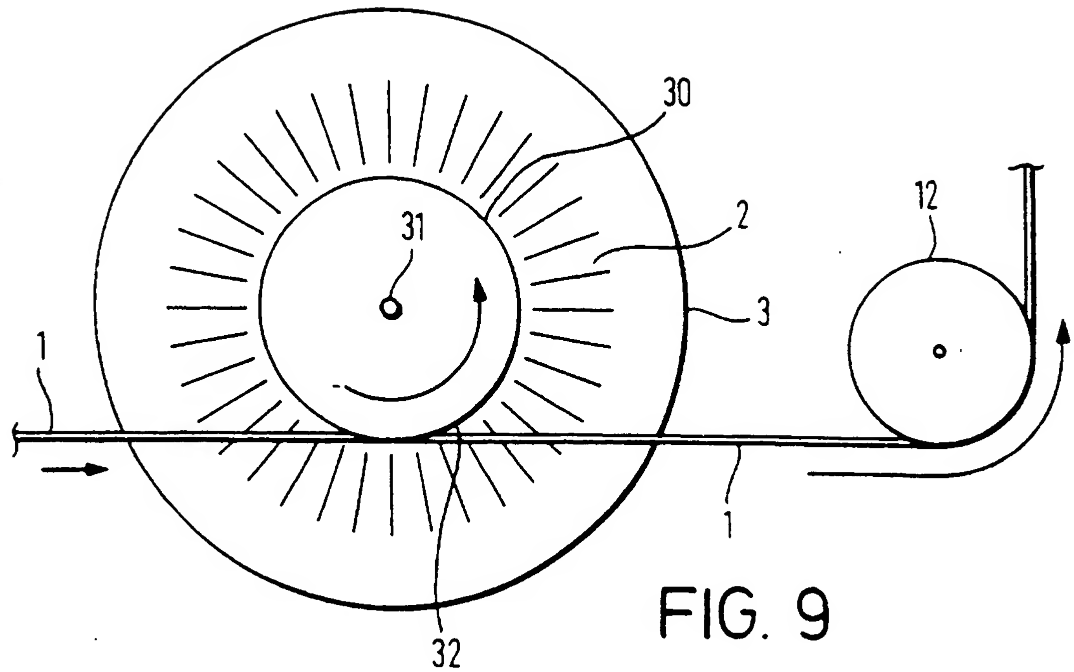

FIG. 9

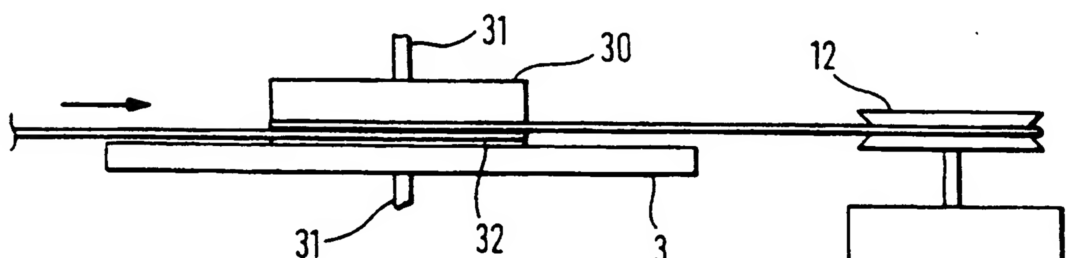

FIG. 10

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 97/00125

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G02B6/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ELECTRONICS LETTERS, vol. 30, no. 10, 12 May 1994, pages 811-812, XP000464233 J. MARTIN AND F. OUELLETTE: "Novel writing technique of long and highly reflective in-fibre gratings" * the whole document * ---	1,18
A	ELECTRONICS LETTERS, vol. 30, no. 16, 4 August 1994, page 1341/1342 XP000468823 ROURKE H N ET AL: "FABRICATION AND CHARACTERISATION OF LONG, NARROWBAND FIBRE GRATINGS BY PHASE MASK SCANNING" * the whole document * ---	1,18,26, 27

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

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Date of the actual completion of the international search	Date of mailing of the international search report
18 April 1997	02.05.97

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Luck, W

Form PCT ISA 210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Int. ...onal Application No
PCT/GB 97/00125

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	ELECTRONICS LETTERS, vol. 31, no. 17, 17 August 1995, pages 1488-1490, XP000528999 M.J. COLE ET AL.: "Moving fibre/phase mask-scanning beam technique for enhanced flexibility in producing fibre gratings with uniform phase mask" * the whole document *	1
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A	US 5 104 209 A (HILL ET AL.) 14 April 1992 see column 2, line 41 - column 3, line 3 see figure 1	1
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X	see column 9, line 13 - line 42 see column 10, line 22 - line 33 see figures 1,3	17

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 97/00125

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		US 5216739 A	01-06-93
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